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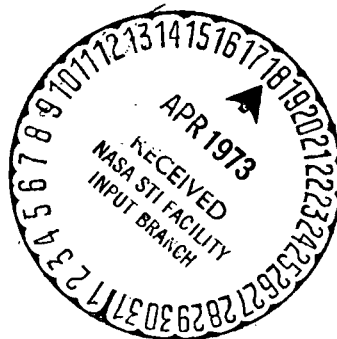
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SPLITTING ALUMINOSILICATES WITH SILICATE BACTERIA

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According to the data of several authors [19,16,6 and others] /39 different strains of *Bac. mucilaginosus* s. n. *siliceus* in liquid nutritive media liberate potassium from silicates in an amount of 5 to 10% of the original quantity of potassium in the silicate.

G. A. Zak in a number of his studies [9,10] indicates that although potassium is liberated from aluminosilicates by silicate bacteria with the formation of silico-organic compounds, this is not accompanied by a deep decomposition of the aluminosilicates, which is confirmed by data from thermographic analysis. In another of his later studies he acknowledges the significant role of silicate bacteria in supplying plants with potassium and writes that in rigid test conditions after boiling aluminosilicates with 20% hydrochloric acid the silicate bacteria is transferred into solution from 7 to 54% of the potassium. "In recalculating for the original soil the amount of potassium liberated from the rock waste of the different soils, in comparable conditions, amounted to 86 to 148.5 mg/per 100 g for yellow soil and podzol and from 175 to 226.5 mg per 100 g for light-chestnut soils and chernozem. Thus the potential capacity for the liberation of potassium from soil aluminosilicates and the scales of this process in the test conditions indicate that the role of bacteria in providing the potassium supply of plants in the soil can hardly be doubted." [11].

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*Numbers in righthand margin indicate pagination of foreign text.

K. I. Surman both in his early studies [15,16] and more recently (1966), with reference to the former by G. A. Zak [9,10], continues to deny the ability of silicate bacteria to break down the aluminosilicate nucleus. K. I. Surman admits the liberation of potassium from silicates to a limited degree—not more than 12.7% of the overall content and only from some complex silicates (for example, mica), in which potassium does not enter the crystal lattice.

However, it is necessary to indicate a general shortcoming in the experiments of the above-named authors. They determined only the potassium, and for a fundamental solution of the problem of the possibility for silicate bacteria to break down the aluminosilicate nucleus it is absolutely necessary to analyze the aluminum and silicon liberated upon the discretion of the aluminosilicate nucleus. We conducted such experiments in 1961-1962.

In order to determine these elements in culture liquid with the splitting of potassium aluminosilicates by silicate bacteria the ordinary methods of analysis proved to be unsuitable, since they did not allow the dynamics of the splitting to be detected, and therefore a special method was developed.

One hundred ml of Aleksandrova no. 27 liquid nutritive medium with 100 mg of silicate after five-day incubation with silicate bacteria were evaporated in porcelain dishes in a water bath. The dry residue was calcined with 10 ml of 30% hydrogen peroxide and again evaporated dry. The residue obtained was dissolved in hot distilled water. The solution was filtered, the filters washed, and the filtrate reduced to 100 ml.

The potassium was determined by the Poluektov flame photometry method (1959), the aluminum and silicon—by a specially developed method on a KSA-1 spectrograph (type 2 spectral plates, light source—alternating current arc, electrodes—carbon, amperage 8A,

distance between electrodes—4 mm, width of slit—0.030 mm, exposure—10 s). The solution study was applied with a micropipette onto specially prepared electrodes, pointed onto a plane, in the form of drops with subsequent drying of each drop. Three drops 0.1 ml each is sufficient for analysis. The electrodes are burned in an alternating current arc. The blackening of the aluminum and silicon lines was measured on an MF-2 microphotometer. The sensitivity of measurements is $1 \cdot 10^{-6}$ g/ml. The reproducibility of results is characterized by a mean arithmetical error of 12%, which is completely acceptable for determining such small quantities of matter and characterizes the given method as quantitative. The experiments were repeated three times. For each test flask with silicate bacteria there was a control in which the potassium, aluminum, and silicon, which were dissolved during the incubation time as a result of the fine division of the silicate and its hydrolysis, were determined. The amount of these elements in the solution of the control flask was subtracted from the results obtained in the productive invariants (Fig. 1, Tables 1 and 2).

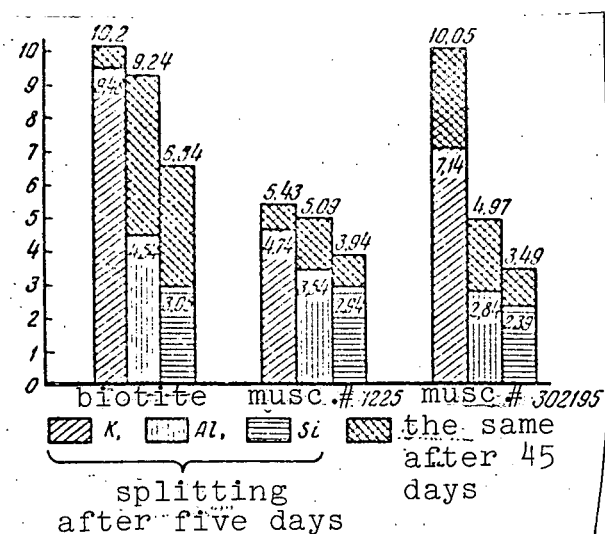


Fig. 1. The splitting of potassium, aluminum, and silicon by silicate bacteria after 5 and 45 days in the case of different aluminosilicates (% of the original amount).

The results of splitting three silicates are shown in Fig. 1 in the form of graphs. The amount of separated potassium, aluminum, and silicon is given in percent of the original contained in 100 mg silicate after subtracting the amount of these elements determined in the controls (taking account of the contamination of reagents and still water, and also the possible extraction of elements from the vessel walls by the silicate bacteria).

One hundred mg of aluminosilicates contained the following original elements: in biotite K_2O - 9.90 mg, Al_2O_3 - 20.03, and SiO_2 - 34.84 mg; in muscovite no. 1225 K_2O - 10.42 mg, Al_2O_3 - 33.03 mg, and SiO_2 - 45.64 mg; in muscovite no. 302195 K_2O - 9.10 mg, Al_2O_3 - 33.36 mg, and SiO_2 - 44.37 mg. Chemical analyses of the overall aluminosilicate composition were made in the analytical laboratory of the All Union Institute of Mineral Resources in Moscow, the results of which and the silicate samples themselves were supplied to us by Prof. M. N. Althausem.

As is seen from Fig. 1, the splitting operated not only for potassium, but simultaneously for aluminum and silicon. These materials are published first. They basically solve the problem of the ability of bacteria to split aluminosilicates, since the aluminum and silicon are the basis of the aluminosilicate nucleus.

The ability of micro-organisms to break down various minerals has been reported in a number of studies by other authors. D. M. Webley, K. B. Duff, and U. A. Mitschell [20] report that the minerals wollastonite, apopheline, and olivin are deeply decomposed by micro-organisms and that x-ray analysis shows their conversion from the crystalline state into an amorphous state. A. N. Ilyaletdinov [12] on the basis of his experimental studies considers the appearance of sesquioxides and silicon in a solution to be the criterion for deep destruction of silicate minerals. The study of the interaction of micro-organisms with aluminosilicates led many

investigators to the conclusion that there are a number of metabolites in the composition of the micro-organisms, "capable of dissolving substances which are difficult to dissolve in water" [12].

The absolute amount of split elements in our experiments did not exceed 5 to 10% even after 45 days of the test. Basically the decomposition process lasts for the first five days, and in the following 45 days it slows down.

The dynamics of splitting biotite by silicate bacteria for each day are presented in Table 1.

Metabolites forming in immiscible solutions in the absence of matter exchange are, in our opinion, the cause of the retardation of this process. This hypothesis is confirmed by Fig. 2, in which the maximum concentration of split potassium, aluminum, and silicon in mg per 100 ml of nutritive solution is graphically depicted for the case of splitting by silicate bacteria for 45 days without subtracting the indices of the control variants and without considering other sources of the accumulation of these elements in the solution. In the case of potassium this amount fluctuates from .47 to 0.84 mg, for aluminum - from 1.39 to 1.85, and for silicon - from 1.55 to 2.28 mg.

As a result of the action of metabolites the splitting of aluminosilicates is at first retarded, and then ceases within the limits of 5-10% of the original amount of potassium, aluminum, and silicon,

In order to explain the influence of the duration of incubation on the process of splitting silicates, we conducted an experiment on splitting biotite with a duration of incubation of 45 days. The dynamics of splitting are presented in Table 2 for a five-day /41 period. From the data in Table 2 it is seen that as a result of the activity of bacteria there was liberated in percent of the original quantity, potassium 10.22, aluminum 9.24, and silicon 6.11.

Table 1. Dynamics of splitting 100 mg of biotite by silicate bacteria and their multiplication for the first five days in no. 27 liquid medium, experiment 25 Feb.-1 March, 1964.

Days of incubation	Potassium found in solution (mg/100 ml)		Potassium liberated by bacteria		Aluminum found in solution (mg/100 ml)		Aluminum liberated by bacteria		Silicon found in solution (mg/100 ml)		Silicon liberated by bacteria		No. of silicate bacteria (million per 1 ml)
	control	introduction of bacteria	mg/100 ml	% of original	control	introduction of bacteria	mg/100 ml	% of original	control	introduction of bacteria	mg/100 ml	% of original	
1	0.20	0.28	0.09	0.91	0.56	1.04	0.48	2.39	0.64	0.88	0.24	0.69	3.0
2	0.27	0.38	0.11	1.11	1.40	2.18	0.78	3.89	1.10	1.70	0.60	1.72	2.5
3	0.45	1.06	0.61	6.16	1.21	2.82	1.61	8.04	1.04	2.70	1.66	4.76	4.5
4	0.42	1.12	0.70	7.07	1.20	3.67	2.47	12.33	1.10	3.82	2.72	7.82	5.0
5	0.40	1.11	0.71	7.08	1.21	3.75	2.54	12.67	1.06	3.79	2.73	7.83	5.0

Table 2. Dynamics of splitting 100 mg of biotite by silicate bacteria after 45 days in no. 27 liquid medium, 17 July-31 August, 1961.

Days of incubation	Potassium (K_2O)			Aluminum (Al_2O_3)			Silicon (SiO_2)		
	found		liberated	found		liberated	found		liberated
	control	with intro- duction of bacteria	mg/100 ml % of original	control	with intro- duction of bacteria	mg/100 ml % of original	control	with intro- duction of bacteria	mg/100 ml % of original
5	0.19	1.14	0.95	0.18	0.10	0.92	0.10	1.16	1.06
10	0.13	1.11	0.98	0.16	1.23	1.07	0.10	1.10	1.00
15	0.13	1.11	0.98	0.16	1.58	1.42	0.10	1.85	1.75
30	0.16	1.15	0.99	0.16	1.90	1.74	0.10	2.38	2.28
45	0.17	1.18	1.01	0.16	2.01	1.85	0.10	2.23	2.13

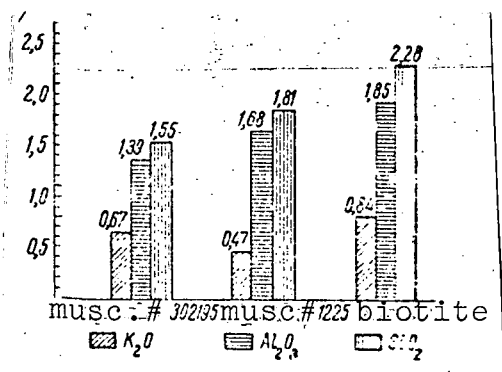


Fig. 2. Maximum concentrations of potassium, aluminum, and silicon in 100 mg of a solution inhibiting further splitting of aluminosilicates.

Thus, the conclusion made in due time by M. I. Ternovskaya [18], that silicate bacteria to some degree are capable of breaking down a number of silicates with the liberation of potassium into solution is completely understandable. However, the decomposition is not so great as to provide potassium supply for plants and thereby to explain the positive effect of the action of silicate bacteria upon agricultural harvests. However, this conclusion was made on the basis of an experiment set on the irremovable liquid nutritive medium no. 27, in which the accumulated metabolites stop the further splitting of silicates.

Many vegetation and field experiments prove the ability of silicate bacteria to provide plants with potassium as a result of their activity. V. G. Aleksandrov [2] grew corn in water cultures and observed an increase in potassium extraction under the influence of silicate bacteria by 53.3%; potassium extraction in sugar beets increased by 92.8 to 86.4% [7]. In corn the use of silicate bacteria raised the potassium content in the kernel from 0.37 to 0.48%, and in the vegetative mass from 1.76 to 2.18. The corn kernel harvest increased by 5.8 and the corn stalk harvest by 19.0 hundred weight per hectare. Thus, the plants were supplied with potassium to a greater degree than the kernel harvest increased. The potassium extraction by the corn harvest under the influence of silicate bacteria proved to be greater than 37.6 kg/hectare. /42

Such a dose of potassium is usually introduced with potassium fertilizers, but it enters the plant less due to the incomplete assimilation of fertilizer potassium [13].

In order to somewhat remove the inhibiting influence of metabolites and to provide for a deeper process of aluminosilicate splitting, G. A. Zak [11] decreased the concentration of organic matter to 0.1-0.01%, decreasing it by 5 to 50 times, which made it possible to liberate up to 40-50% of potassium from the original amount. In his experiments the absence of nitrogen in the nutritive medium significantly increased the amount of liberated potassium. For example, in one of the experiments in a medium without nitrogen up to 31.3% of the potassium was liberated and with nitrogen only 14.9%. He noted the interesting fact that the energy of splitting silicates is not connected with the amount of cells developing in the medium.

Consequently, the conclusions of G. A. Zak confirm the suitability of no. 27 medium without nitrogen for studying the ability of bacteria to split aluminosilicates. Observations of the multiplication of bacteria in the first 5 days do not show their destruction (Table 1).

It is possible to remove the influence of metabolites, in our opinion, by periodically changing the solution. On the average, from 8 of our experiments in which the culture liquid was changed from 6-10 times, after 30 days the following totals were observed (in percent of original): K_2O - 51.74, Al_2O_3 - 57.83, and SiO_2 - 50.28.

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